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ABSTRACT

The classification of intelligence has been a prime interest to many for over three-quarters of a century. The Wechsler scales of intelligence and the development of factor analysis have both played major roles in the shaping of psychometric thought. An examination of this joint history by means of a review of the factor analytic studies of the Wechsler scales reveals the trends and inconsistencies in this area of mutual concern. It is now appropriate and important to bring this literature together for a united treatment as much of it is disjointed and contradictory, with many researchers remaining unaware of recent developments. The rationale for investigating the factor structure of the Wechsler scales is presented. An introduction to the number of factors problem is offered, as well as discussion of the most frequent types of analyses. Reports of changes in the factor structures are presented, and finally, new directions for future research are introduced. (Author)

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Factor Structure of the Wechsler Scales: A Brief Review

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Abstract

The classification of intelligence has been a prime interest to many for over three-quarters of a century. The Wechsler scales of intelligence and the development of factor analysis have both played major roles in the shaping of psychometric thought.

An examination of this joint history by means of a review of the factor analytic studies of the Wechsler scales reveals the trends and inconsistencies in this area of mutual concern. It is now appropriate and important to bring this literature together for a united treatment as much of it is disjointed and contradictory, with many researchers remaining unaware of recent developments.

The rationales for investigating the factor structure of the Wechsler scales is presented. An introduction to the number of factors problem is offered, as well as discussion of the most frequent types of analyses. Reports of changes in the factor structures are presented, and finally, new directions for future research are introduced.

Factor Structure of the Wechsler Scales: A Brief Review

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The development of the classification and measurement of human intelligence has shared a joint history with the development of factor analysis. For this reason, factor analysis has become a prime tool for psychologists and those interested in classification and measurement. One effect of this association can be seen in the style in which we currently address many aspects of human intelligence. Some researchers have criticized the use of factor analysis and recommended avoiding its application because of "subjective" decisions, indeterminacy, ancillary variables and reification. Topics of controversy include the validity of a Spearman-like "g" factor, alternative axis orientations, and the number of factors.

A review of the factor analytic studies of the Wechsler scales is a convenient means of addressing these issues and should bring new light to bear on a topic of importance to both clinicians and researchers. This literature will permit a description of the changes in how intelligence has been, is now, and will be, described. Major areas include the reason for investigating the factor structure, the number of factors problem, considerations of simple structure, changes in the factor structure, and a look a new directions for future research.

Why Investigate the Factor Structure of the Wechsler Scales

The factor analyses of the Wechsler scales reported here are primarily exploratory in nature. That is, factor analysis has been applied to reduce the dimensionality of the tests, but without a theory guiding the construction or description of the new dimensions. Such an exploratory approach is predicated on the assumption that the correlation among tests is sufficient evidence for supposing the existence of underlying abilities. These latent dimensions are only tapped by the actual subscales. Factor analysis permits an inspection of the formerly hidden facets. Alternatively, one may have an hypothesis about the structure of human abilities and use factor analysis as an objective means of substantiating the hypothesis. This difference in orientation is seen in the different factor structures of the Wechsler scales reported by American and British factor analysts. The British tradition is to extract a general "g" factor, then to extract group dimensions of verbal:educational and mechanical:performance. The American tradition approaches the problem from a different perspective. Verbal and Performance abilities are first order factors, and the general dimension is seen as a second order factor. Regardless of orientation, factor structure is important to the interpretation of latent abilities across varying samples, time, or both.

Thus, study of the factor structure of the Wechsler scales is important for the general description of human intellectual abilities, hypothesis formation, and confirmation. The advantages of using the Wechsler scales for this type of ongoing research rests in their high internal consistencies, wide use, and extensive history of publications. It is both the parsimony of description and the need for a clear view of what is being measured that encourage factor analytic studies of the Wechsler scales. It is now appropriate to seek an integration of findings

in this factor analytic literature, as much of it has been disjointed. Table 1 presents such an overview.

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Insert Table one about here

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Summaries of authors, samples, and information about the analyses are presented. This information has been compiled into tabular form to demonstrate the wide range of applications, samples, and rationales that have been associated with the factor analytic investigations of the Wechsler scales. Articles are presented in order of publication so that the nature of developments may be accurately temporally portrayed. The tests analyzed in the article or report are listed by their abbreviations, WB being the Wechsler-Belevue, the first in the family, the WAIS, Wechsler Adult Intelligence Scale, the WISC, the Wechsler Intelligence Scale for Children, and the WPPSI, the Wechsler Preschool and Primary Scales of Intelligence. The inclusion of other tests usually represents an attempt to validate a Wechsler scale against another assessment device, or, as in the case of Riegel and Riegel (1962), the WB and the WAIS were used to validate a German version of the WAIS, the HAWIE. The "sample used in study" column also represents the breadth of sampling associated with these scales since their inception. Similarly, the wide range of descriptive terms for the factor analytic method applied indicate the changing trends in the application of this type of analysis. The factor analytic method, type of rotation, and number of factors before and after rotation, (i.e., number of unrotated, and rotated factors), should be viewed together. This should also provide the interested reader with a valid description of the state of the art for the last forty years or so. Conger and Conger (1975)

in their WISC study refer to Varimax as row normalized Varimax. The difference in terminology, while correct, suggests a distance from the psychometric literature. This is certainly not a critical point, but it is suggestive of the population of producers and consumers of Wechsler-scale relevant information. Yet as with all factor analytic studies, including these, certain technical concerns remain of interest as well. Therefore, while reviewing the contents of table one, discussion is presented on a series of questions which relate to the application of the factor analytic method to the Wechsler scale data. Attempting to derive the correct number of factors with which to portray human intellectual functioning on the Wechsler scales is one such ongoing factor analytic issue.

Number of Factors Problem

The question of the correct number of factors on the Wechsler scales is recognized as being a contentious issue. The correct number of factors would allow for accurate description and replication, as well as meeting certain statistical criteria. Importantly, this issue has never really been resolved. Answers vary from Guilford's (1967) 120 factor "cube of intellect" model to a 1, 2, or 3 factor solution. Wechsler developed his tests so as to be essentially batteries to assess general intelligence. Unrotated matrices of factor loadings always show a large first factor. Inspection of a typical plot of eigenvalues correspondingly shows this large first dimension. A sampling of the various "number-of-factors" rules (cf, Cattell, 1966; Cattell and Jaspers, 1967; Kaiser, 1958, 1960; Montanelli and Humphrey, 1976; Wrigley, 1960) shows 1 or 2 factor solutions to be preferable. For instance, our experience with Velicer's (1976) recent but rarely cited MAP test, usually recommends retaining only one factor. The three factor solution has been the solution typically reported

within the literature. Inspection of table 1 shows that most authors have retained three rotated factors to account for Wechsler scale responding. The rise of the three factor solution can be traced to Cohen (1952a,b, 1957a, b) and associates. Cohen interpreted anywhere from three to five factors as being "significant" and introduced the Memory or Freedom From Distractability dimension. Hammer (1950) actually was first to report this memory dimension. This popular three-factor solution consists of a Verbal, Performance, and the above "Memory" factor. The review of the factor analytic studies summarized in table one serves to show the range of "correct" numbers of factors. Typically, a three factor solution is retained by most authors. The number of factors rules cited above suggest retaining one or two factors. The latter is consistent with Wechsler's development of the tests as essentially batteries to assess general intelligence. Applied researchers prefer to retain the memory factor, thus giving rise to the three factor solution. The three factor solution can be seen as consistent. The predictive validity of the solution has been demonstrated by Yule, Gold and Busch (1981). Their eleven year longitudinal study of Wechsler scales revealed a consistent three factor structure, with changes in raw score scatter and elevation only. Importantly, Wechsler Preschool and Primary Scales of Intelligence (WPPSI) administered to 5 1/2 year old children predict abilities eleven years later with 90% accuracy.

Considerations of Simple Structure

Rotating factor loadings to a simple structure criterion after Thurstone (1947) is usually considered an acceptable means of dealing with the issue of rotational indeterminacy. Positions of axes are indeterminate because any data set has an infinite number of different sets of reference

axis positions solutions. (Indeterminacy also arises due to the problem in specifying the exact length of the standardized data vector. Since this length is contingent upon the defining all of the common factors, and this is rarely accomplished, the true value is also said to be indeterminant). Thurstone's (1947) simple structure criterion describes most phenomena well, and is probably the best solution for the common factor model -- a model entirely appropriate for such exploratory studies. It invokes the fewest factors and this aids interpretation. For the same reason, it is parsimonious, since it only requires a small number of factors to explain any phenomena. Thurstone also specified that a factorial solution should be invariant -- that similar clusters of similar variables should always been seen, regardless of the other variables. For these reasons, simple structure is popular, easy to use and interpret. Kaiser's (1958) Varimax is considered to approximate closely the simple structure solution. The frequency of Varimax rotations in table one is evidence of the popularity of simple structure.

Using simple structure when assessing factor similarity is not recommended, even though authors attempt this. Comparing independent simple structure rotations introduces a confounding in that the data matrices are being made more different by treating them separately. Cattell (1944; Cattell & Jaspers, 1955) has presented a way of preprocessing the data matrices so that this increased independence of the data is avoided. Parallel proportion profiles serves to make all data sets representative of the overall data set, and statements about how similar one set is from the overall set can be made with impunity.

Another point of caution associated with simple structure is that it cannot be used in a confirmatory sense. It is an exploratory technique, it does not draw upon causal models or explicit hypotheses. Therefore its use in causal modelling, explicit hypothesis testing or theory construction must be avoided. At best it provides a narrative description of readily evident aspects of the factor solutions under consideration. There is no question of its historical value in terms of describing human abilities, as measured by the Wechsler scales. Alternatives to simple structure, exploratory-type factor analyses of human intellectual abilities have only recently began to be disseminated. Before they are discussed, however, discussion is presented on a topic which was the reason for the first published factor analysis of a Wechsler scale. This is the question of whether or not there are actual changes in the factorial nature of human intellectual abilties with age or other cohorts.

Changes in the Factor Structure

Precise knowledge of changes in the structure of intellectual abilities is important for social policy and the understanding of non-normative groups. Inspection of the column of samples in table one illustrates the range of sample that have been assessed. Factor structures have been reported for various ages, cultures, neuropsychological, pathological, disabled, brain-damaged and epileptic samples. Reed and Fitzhugh (1967), for instance, factored Wechsler Bellevue (WB) and WAIS scores from brain-damaged subjects. This study is representative of this literature. They reported no differences between the normative data and their own. Nor were there structure differences between the WB and the WAIS. Furthermore, they reported both two and three factor solutions. Russell (1972) reported that the factor structure actually remains constant

while WAIS raw scores are affected by brain damage. Investigation of changes associated with aging have published similar conclusions. Balinsky (1941) was first to try to measure these hypothesized changes. He found an on-again, off-again general factor, and a varying number of significant factors. Later publications, however, agree that some raw scores decrease with age, but that this is confounded by elderly learning imparement, levels of education attained by the younger comparison groups, and other cohorts. Few longitudinal studies exist, barring definitive descriptions of change over time. Garrett's (1946) differentiation hypothesis, where intellectual factors become more differentiated with age, has been rejected. Cohen (1959) found that children had a smaller or more limited range of intellectual functioning than was once thought. In short, the WB, WPPSI, WISC, and WAIS have all been shown to posses the familiar three factor solution -- across all samples.

New Directions for Future Research

This brief review has attempted to introduce over forty years of factor analytic research with the Wechsler scales. Descriptions of the factor structure for many diverse groups have been documented. Yet the majority of the publications have been atheoretical. The aims have rarely been to develop an encompassing theory of the mental abilities reflected in the Wechsler scales. Some see these articles as a parsimonious means of dealing with conflicting research reports. This is a point in favour, and has probably helped to disseminate such knowledge.

Since the goal of all of this research is to describe the latent structure of human intellectual abilities, means of adding to this store of information should be discussed. McArdle and associates have provided a

great deal of information on structural equation modelling data for the collective Wechsler scale data (cf, McArdle, 1980). This affords an explicit statement of the effects of residual variance, something that traditional factor analysis cannot accomplish. The general theory is based upon Cattell's (1971) developmental theory of fluid and crystallized intelligence. McArdle has generated a nomological network which describes general fluid and crystallized factors, a dimension of "broad speediness", short-term acquisition and retrieval, and tertiary (long term) storage and retrieval. It has been mentioned that traditional studies have been atheoretical and static. This structural equation modelling approach is theoretical, aids in theory construction and testing, and is dynamic. Moreover, it gives voice to the effects of residual correlations that were silent before.

Left, right and front, back brain differences have been difficult to assess with the Wechsler scales. Future publications might report physiological data (ie, EEG patterns) as correlates of Wechsler scale performance. This would address the question of which areas of the brain are truly responsible for which subtests. Similarly, sex differences have always been a difficult topic, but the incorporation of additional assessment devices and stratagems might make this an easier topic to collect reliable information on.

There has been nearly half a century dedicated to description. Now must surely be the time to extend our search to the realm of explanation. To do so, new methods are required. Structural equation modelling, with its explicit statements of even minor effects, and contributions to theory development certainly holds one key to this future puzzle. So must the

evolution of the test battery itself. Including Wechsler scale data along with other correlates of intelligence, such as reaction and physiological assessment, will extend our knowledge of the processes involved, their location, and best means of measurement. There is an impressive history of data collection. The incorporation of this wealth with new theoretical methods and additional sources of information will yield a fruitful relationship.

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Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Balinsky (1941)	WB	standardization	centroid	Guilford(1936)	4/2
Birren (1950)	WB	elderly	centroid	Thurstone (1947)	n/a/4
Hammer (1950)	WB	standardization	centroid	Burt (1940)	3/4
Birren (1952)	WB	elderly	centroid	Thurstone (1947)	n/a/4
Cohen (1952a)	WB	3 neuropsychiatric groups	centroid	Thurstone (1947)	n/a/3 (per group)
Cohen (1952b)	WB	same as above	centroid	Thurstone (1947)	n/a/3/ (per group)
Davis (1956)	WB	high school S's	centroid	Zimmerman (1946)	11/10
Cohen (1957a)	WAIS	standardization & 60-75 yr. olds	centroid	Thurstone (1947)	4/5 except for oldest sample: 4/4
Cohen (1957b)	WAIS	same as above	centroid	Thurstone (1947)	4/5 except for oldest sample: 4/4

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-2

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Saunders (1959)	WAIS	high school &	maximum likelihood	confirmatory	n/a/2
Maxwell (1960)	WAIS	psychiatric	n/a	n/a	11/3 to 5
Riegel (1960)	WAIS	standardization German WAIS c/w elderly sample	principal components	n/a	n/a/2
Baumeister & Bartlett (1962a)	WISC	standardization & retardates	centroid	Wherry (1959)	n/a/3
Baumeister & Bartlett (1962b)	WISC	same as above	centroid	Wherry (1959)	n/a/3
Riegel & Riegel (1962)	WB, WAIS, HAWIE	aged samples	principal components	orthogonal	4/4
Berger et al (1964)	WAIS	psychiatric	centroid	Carroll (1957)	7/4
Dennerll et al (1962)	WAIS, WISC	epileptic children & adults	principal axes	Carroll (1957)	5/3

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-3

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Green & Berkowitz (1964)	WB	residents of a veterans facility	centroid	oblimax	n/a/4
Osborne (1964)	WISC	negro & white children	n/a	n/a	10/10
Radcliffe (1966)	WAIS	standardization	principal components	Neuhaus & Wrigley (1954)	(note 2)
Sprague & Quay (1966)	WAIS	retardates	principal axes	Kaiser (1958)	n/a/4
Semler & Iscoe (1966)	WISC	black & white children	n/a	n/a	3/2 (both races)
Osborne et al (1967)	WISC	3 age levels	principal components	Kaiser (1958)	6/12
Reed & Fitzhugh (1967)	WB, WAIS	chronic cerebral	principal axes	Kaiser (1958)	(WB) n/a/2 (WAIS) n/a/3
Shaw (1967)	WAIS	college sample	principal axes	(oblique simple structure)	3/2

Table 1: Short Review of the Factor Analytic Studies of The Wechsler Scales Table 1-4

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Savage & Bolton (1968)	WAIS,ART MWLT,MPI	elderly, normal & pathological sample	principal components	Kaiser (1958)	6/6
Silverstein (1969)	WAIS, WISC WPPSI	standardization	principal axes	Kaiser (1960)	6/2
Silverstein (1969)	same as above		principal axes	Kaiser (1960)	6/2
Zimmerman et al (1970)	WAIS	cerebral dysfunction, diffuse & lateralized brain damage	principal components	Kaiser (1958)	6/3
Leton (1972)	WISC, ITPA	school-age children	principal components	Kaiser (1959)	n/a/7
Russell (1972)	WAIS	brain-damaged patients	principal components	Kaiser (1958)	3/3

Table 1: Short Review of the Factor Analytic Studies of The Wechsler Scales Table 1-5

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Coates & Bromberg (1973)	WPPSI	standardization	principal components	Kaiser (1958)	4/3
Hollenbeck & Kaufman (1973)	WPPSI	standardization	1) principal components,	Kaiser (1958)	n/a/2
			2) Kaiser's little jiffy,	Kaiser (1970)	n/a/2
			3) principal factor	Kaiser (1958)	n/a/2
Silverstein (1973)	WISC, WAIS	retarded	principal factor	Eber (1966)	3/3
Silverstein (1973)	WISC	3 ethnic groups caucasians, blacks & chicanos	principal factor	Eber (1966)	n/a/2
Vance & Wallbrown (1973)	WISC-R	referred children & adolescents	Wherry & Wherry (1959)	n/a	3/3

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-6

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Wallbrown et al (1973)	WPPSI	standardization	Wherry & Wherry (1959)	n/a	3/3
Wallbrown et al (1974)	WAIS	standardization	Wherry & Wherry (1959)	n/a	3/3
Kaufman & Hollenbeck (1974)	WPPSI	blacks & whites	three methods	Kaiser (1958)	4/3
Rugel (1974)	WISC	disabled readers	principal components	Kaiser (1958)	n/a/3
Wallbrown et al (1974)	WISC, ITPA	disabled readers	Wherry & Wherry (1959)	n/a	3/3
Wallbrown et al (1974)	WAIS	standardization & old age sample	Wherry & Wherry (1959)	n/a	3/3
Conger & Conger (1975)	WISC	standardization	canonical analysis	row normalized varimax	n/a/3 canonical variates
Kaufman (1975)	WISC-R	standardization	principal components	Kaiser (1958)	n/a/2

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-7

Author & date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Klinger & Saunders (1975)	WAIS	college sample	Saunders (1960)	Saunders (1962)	n/1/5
Muhkerjee (1975)	WPPSI	standardization	principal factor	equimax	n/a/3
Van Hagen & Kaufman (1975)	WISC-R	retardates	principal components	Kaiser (1958)	5/3
Wallbrown et al (1975)	WISC-R	standardization	Wherry & Wherry (1959)	n/a	3/3
Williams (1975)	WAIS, WISC	parents & (male) children	principal factor	oblimin (Harman, 1967)	n/a/2
Ramanaiah et al (1976)	WISC	standardization	multiple groups	confirmatory	n/a/2
Reed & Fitzhugh (1976)	WB, WAIS	chronic cerebral dysfunction	principal components	Kaiser (1958)	5/2
Vance et al (1976)	WISC	disadvantaged black & white children	Wherry & Wherry (1959)	n/a	3/3

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-8

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotation Method	No. of Factors
Landsell & Donnelly (1977)	WAIS, CTT,TT	psychiatric & neurological patients	principal axes	Horst (1965)	4/3
Silverstein (1977)	WISC-R	standardization	principal axes	Kaiser (1958)	3/3 & 2/2
Stewart (1977)	WISC	3 diagnostic groups	image analysis	n/a	n/a/3
Blaha & Vance (1977)	WISC-R	disabled readers	Wherry & Wherry (1959)	n/a	n/a/4
Puhan (1979)	WAIS	1) 18-1 9 yrs, 2) 25-34 yrs.	principal axes	Kaiser (1958)	1) n/a/4 2) n/a/3
Ramanaiah (1979)	WAIS	standardization	multiple group	Kaiser (1958)	n/a/2
Ramanaiah & Adams (1979)	WAIS, WPPSI	standardization	multiple group	Kaiser (1958)	n/1/2

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-9

Author & Date	Test(s)	Sample Used In Study	Factor Analytic Method	Rotational Method	No. of Factors
Fowler et al (1980)	WAIS	eplileptics & normals	maximum likelihood	Kaiser (1958)	3/2
Richards et al (1980)	WISC-R	epileptic children	maximum likelihood	n/a	n/a/2 or 3
McMahon & Kunce (1981)	WISC, WISC-R	normal & execptional children	n/a	Kaiser (1958)	n/a/3
Naglieri (1981)	WISC-R	learning disabled	principal components	Kaiser (1958)	5/3
Blaha & Wallbrown (1982)	WAIS-R	standardization	Wherry & Wherry (1959)	n/a	3/3
Glass (1982)	WAIS-R	standardization	principal factor	Kaiser (1958)	4/2
Harlow et al (1982)	WISC-R	standardization	Schmid-Leiman (1957)	oblique, simple structure	n/a/3 + "g"

Table 1: Short Review of the Factor Analytic Studies of the Wechsler Scales Table 1-10

Author & Date	Test(s)	Sample Used In Study	Factor Analytic method	Rotational method	No. of Factors
Naglieri & Kaufman (1982)	WAIS-R	standardization	principal components	Kaiser (1958)	4/2 or 3
Silverstein (1982)	WAIS-R	standardization	principal factor	Kaiser (1958)	n/a/2 + "g"
Parker (1983)	WAIS-R	standardization	principal factor	Kaiser (1958)	4/3